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US Army Research Laboratory

Summary of the Sixth Persh Workshop: Corrosion Policy Guiding Science and Technology

by Pauline M Smith

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by Pauline M Smith
Weapons and Materials Research Directorate, ARL

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14. ABSTRACT The Persh Workshop is a series of Department of Defense (DOD)-level workshops initiated by the Defense Science and Technology Reliance 21 Materials and Manufacturing Process Community of Interest, which recognizes that direct communication between the stakeholders is a valuable way of identifying common issues that should be addressed or further assessed. This Sixth Persh Workshop's topic "Corrosion Policy Guiding Science and Technology" was selected because of its current relevance to the DOD acquisition and sustainment communities. This workshop consisted of 2 days of discussions with panel sessions and keynote speeches. Attendees were represented by government, industry, and academia. The workshop resulted in a number of very important observations about workforce developments and defined them based on the inputs from all participants. A number of very significant questions and challenges were defined that subsequently led to the generation of pertinent recommendations for the technical community to consider for further actions.			
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Contents

List of Figures

List of Tables

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Executive Summary

The research scientists and policy leaders who have worked together to address corrosion problems on military assets met to discuss corrosion policies that guide science and technology (S&T). The Sixth Persh Workshop was held at the Institute for Defense Analyses in Alexandria, Virginia, on 11–12 February 2015. The workshop focused on corrosion policy guiding S&T and provided an opportunity for representatives from industry, academia, the Department of Defense (DOD), and other government agencies to examine how academia, industry, and DOD identify opportunities to address corrosion issues. The term "corrosion" refers to the deterioration of a material or its properties due to a reaction of that material with its chemical environment. For decades, corrosion has been one of the military's most formidable problems, degrading the structural health of mainly metal-based assets, including sea, air, and ground systems, as well as their associated support equipment. The military services recognize the insidious and pervasive effects that corrosion has had on infrastructure and equipment/materiel readiness and personnel safety. These substantial negative impacts include reduced availability, deteriorating performance, and ever-increasing total ownership cost of materiel and infrastructure.

As an example, the annual corrosion-related costs for the DOD during the 2011 fiscal year (FY) were over $23 billion[1] according to a study commissioned by the DOD's Corrosion Prevention and Control Integrated Products Team. Decreased readiness, increased manpower requirements, and significantly higher life-cycle sustainability costs are continuing factors that force the DOD to focus on the preventable issues of corrosion. Some of the important key issues and questions that were explored during this workshop include improved interaction between policy and S&T personnel; balancing public law and policy; converting S&T initiatives into policy; integrating maintenance and reliability strategies; prediction and management of the acquisition cycle; unique government and laboratory-specific policy/philosophical differences; and how industry and academia can help with important issues, such as monitoring and implementing structural health monitoring (risk, ownership, design, maintenance considerations versus operational factors).

[1] US Government Accountability Office (GAO). The Department of Defense's fiscal year 2012 corrosion prevention and control budget request. Washington (DC): GAO; 2011 Apr 13. Report No.: GAO-11-490R [accessed 2015 Oct 7]. http://www.gao.gov/products/GAO-11-490R.

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1. Introduction: The Defense Science and Technology Reliance 21

The Defense Science and Technology Reliance 21 Materials and Manufacturing Processes (M&MP) Panel is one of the overarching frameworks for the joint planning and coordination of all Department of Defense (DOD) (science and technology [S&T]) programs and initiatives. There are 17 Communities of Interest (COIs) within Reliance 21 that ensure a comprehensive and collective understanding of the priorities, requirements, and opportunities of the DOD organizations that manage critical S&T resources. The Defense Science and Technology Reliance 21 M&MP COI identifies and covers technologies that are important to the manufacturing processes converting materials into system components, as well as the fundamental scientific and engineering fields that are needed to maintain and enhance the US Defense capability.

The purpose of the M&MP COI is to provide national leadership coordinating technology-based options for providing advanced materials and processes to the DOD. The COI achieves these objectives through direct integration and coordination of 8 key technology fields, assuring continuing collaborations with the best expertise available in related activities across broader materials and manufacturing fields, whether domestic or international.

The current cross-DOD technology teams making up the M&MP COI include subject matter experts (SMEs) for materials and manufacturing processes in the following areas: Structures and Protection; Propulsion and Extreme Environments; Sensors, Electronics, and Photonics; Power and Energy; Readiness; Individual Warfighter; Civil Engineering; and Corrosion. Its goals are to strengthen S&T planning by improving the integration of S&T investments with a DOD-wide strategic view that incorporates all the service/agency plans and by enhancing the coordination between S&T communities within the DOD. Major accomplishments and deliberations included assessing the technical health of DOD M&MP investment areas, identifying technology trends and emerging S&T opportunities, and facilitating collaborations among stakeholders to optimize cross-service cooperation and opportunities.

The Defense Science and Technology Reliance 21 M&MP COI principal members are as follows:

- Dr Julie Christodoulou, Navy Principal and Chair
- Dr Lewis Sloter, Office of the Assistant Secretary of Defense Principal
- Dr Peter Matic, Navy Principal

- Dr Daniel Miracle, Air Force Principal
- Dr Jeff Zabinski, Army Principal
- Mr Dick Urban, Defense Advanced Research Projects Agency Principal
- Dr Steven Wax, Defense Threat Reduction Agency Principal

The committee for this Sixth Persh Workshop, "Corrosion Policy Guiding Science and Technology", included the following personnel:

Chair: Pauline Smith, Deputy Chief, Coatings, Corrosion and Engineered Polymers Branch, US Army Research Laboratory

Planning Committee:

- Edward Lemieux, Director, Center for Corrosion Science and Engineering, Naval Research Laboratory (NRL)
- Dr Virginia DeGiorgi, Head (Acting), Multifunctional Materials Branch, NRL
- Dr Lewis Sloter, Associate Director, Materials & Structures, Office of the Secretary of Defense (OSD), Director, Defense Research and Engineering
- Dr Airan Perez, Corrosion Control Program Officer, Office of Naval Research, and Office of the Assistant Secretary of Defense for Research and Engineering
- Ronald Pendleton, Engineer and Tech Transition Program Manager at the US Air Force Research Laboratory (AFRL)
- William Hong, Research Staff Member, Institute for Defense Analyses
- Dr Jennifer Wolk, Materials Engineer, Naval Surface Warfare Center Carderock Division
- Monica L Poelking, Chief Strategist for the Materials and Manufacturing Directorate, AFRL
- Warren Johnson, Universal Technology Corporation (UTC)
- Robert Rapson, UTC
- Tracy Tapia, UTC

2. The Persh Workshop

The Persh Workshop was conceived as a forum that would include a diverse audience for in-depth investigations and discussions of issues of common interest and relevance to the DOD and, specifically, the M&MP community. At the same time, workshop participants also recognized that direct communications among the stakeholders was a valuable way of identifying common issues that should be addressed. The DOD M&MP engineering community is now facing an increased demand for defense materials that exhibit multiple functionalities and that combine the best attributes of performance and personnel protection. To meet this requirement, DOD, industry, and academia are challenged to develop and apply knowledge-based performance tools and novel technologies that can successfully reduce redundancies and create better synergies. The topic of the Sixth Persh Workshop, "Corrosion Policy Guiding Science and Technology", is therefore appropriate and timely.

The Persh Workshop provides a platform for rapidly assessing issues that the M&MP community is currently facing in a setting that does not exist in traditional forums; it incorporates matters that provide context using interactive panel discussions that explore and probe issues and opportunities. The primary goals are to encourage the open and free exchange of ideas, stimulate broad discussions of key issues, and help frame strategic investment decisions and related policy options. Attendance at these Persh Workshops is by invitation only to diverse stakeholders (who have perspectives and responsibilities ranging from technologies to policies as well as from research to application fields) who can engage in idea-generating discussions. The outcomes of each Persh Workshop are analyzed to develop assessments and/or recommendations for submission to the DOD and for distribution to the participants. Each workshop addresses a distinct topic (in this case, materials degradation) of strategic importance, including thermal management materials, data mining, standardization, and educational collaborations. The forum is unique in that it provides a holistic look at a subject in the context of national security and enables the identification of areas where the M&MP community should focus.

The workshop is named in honor of Mr Jerome Persh, an inspirational leader of the DOD materials development community for almost 4 decades, recognizing his longstanding and exceptional leadership in the defense materials community. He was especially recognized for his service as the Staff Specialist for Materials and Structures in the Office of the Director of Defense, Research and Engineering (Advanced Technology) in the Pentagon from 1967 to 1996. In that position, he provided excellent policy assistance and program guidance to the military departments and defense agencies. He made many noteworthy contributions to the development of key DOD materials technologies, including composites and laser protection materials. As a result of his vision and significant achievements, he received numerous government and industry awards and, upon his retirement, remained active in an advisory capacity throughout his life.

3. Background

Corrosion is a serious problem throughout the DOD. The US Congress, recognizing the severe impact of corrosion on military equipment and infrastructure, enacted legislation to address this DOD-wide problem: Section 1067 of the Bob Stump National Defense Authorization Act for Fiscal Year 2003, Public Law Number 107-314, enacted 10 USC 2228 (Corrosion Policy and Oversight Office 2011). The law requires that the DOD designate a responsible official or organization to oversee corrosion prevention and mitigation, and directs activities and those charged with directing the long-term strategy to reduce corrosion and its effects. The DOD spends an estimated $23 billion in corrosion-related maintenance and repairs every year. The Government Accountability Office reported that "current cost estimates, readiness, and safety data indicate that corrosion has a substantial impact on the military equipment/materiel and infrastructures" (GAO 2011). In 2011, they also concluded that the DOD and military services currently do not have an effective approach for preventing and mitigating corrosion.

Corrosion affects military readiness, so corrosion prevention and control (CPC) have a high priority for the DOD since CPC is a corrective and preventive measure used to mitigate corrosion—these activities constitute more than 25% of its total maintenance costs (DSB 2008a). In February 2008, Congress enacted Section 371 of the 2008 National Defense Authorization Act, which amended Section 2228 of Title 10, United States Code, to strengthen the DOD Corrosion Prevention and Control Program (CPCP) by enumerating specific organizational changes and adding new requirements. The organizational changes included eliminating the DOD Corrosion Executive, elevating the Special Assistant for Corrosion Policy and Oversight (CPO) to Director of CPO, assigning the former duties of the Corrosion Executive to the Director of CPO, and directing that the CPO Director report directly to the Undersecretary of Defense for Acquisition, Technology and Logistics (USD [AT&L]). This designated responsibility for the prevention and mitigation of corrosion for DOD's military equipment and infrastructures to the Director of CPO, which included the management and oversight of corrosion matters as they relate to the acquisition; sustainment; and research, development, test, and evaluation (RDT&E). The amendment also mandated coordination of corrosion courses with the Defense Acquisition University; the development of relevant corrosion directions and instructions; increased interactions with industry, agencies, trade associations, academic research and educational institutions, and scientific organizations, such as national academies; and the establishment of Memoranda of Agreement for joint funding agreements with public-private partnerships, university partnerships, and other cooperative agreements.

To make these advances and reduce those costs, it is essential that appropriate policies be adopted by including science-based understanding, predictive tools, communications, education, performance-based acquisition, and performance-based logistics within the S&T portfolio. While corrosion education has improved over the past several years, progress in developing advanced DOD technologies and implementing improved practices in corrosion control has been slower. Whenever corrosion problems are not addressed in a timely manner, the readiness and safety of weapons, equipment, and facilities can be substantially degraded, resulting in high-cost repairs. Corrosion mitigation is thus a key cost-effective approach for system maintainability and reduced life cycle costs.

The Defense Science Board (DSB) Task Force assigned to conduct a thorough review of corrosion practices in the DOD estimated that 30% of current corrosion costs could be avoided through proper investments in the prevention and mitigation of corrosion during the design, manufacture, and sustainment processes for materiel and infrastructure systems (DSB 2008b). Additionally, the DSB found that increased CPC efforts were critical to adequately address the pervasive and costly effects of corrosion on equipment and infrastructure (DSB 2008a). However, based on fiscal constraints, DOD has been able to fund only about one-third of its identified necessary corrosion projects. The DSB conclusion was that executive leadership and commitment addressing systemic policy, management, design, manufacturing, and education issues would be required to produce a credible life-cycle cost reduction through corrosion mitigation.

Since the corrosion community is relatively small, it must expand in size and capability to meet the growing demand for corrosion SMEs to assist with future weapon systems acquisitions. The importance of having corrosion expertise in the future workforce has not been well investigated. While many individual programs are available to address the education and development of corrosion expertise, there has been no comprehensive effort to establish specific learning goals and qualifications. Corrosion education programs are currently provided by several academic institutions, technical societies, industry, and DOD, where these include capstone projects, competitions, and other corrosion-related activities. A comprehensive assessment of specific corrosion SME demands related to the current training availability is needed to expand educational opportunities for these most needed areas.

The overall corrosion prevention and mitigation strategy is to inculcate a DOD-wide culture that considers the long-term effects of corrosion, sets boundaries on the cost of corrosion, implements sound corrosion prevention and mitigation policies for both equipment/materiel and infrastructures, and establishes realistic metrics to evaluate the effectiveness of these policies and the resulting programs. This culture permeates the military, industrial, and academic sectors, creating new paradigms for characterizing, preventing, and treating corrosion and mitigating its effects. As such, corrosion was selected as the workshop focus because of its current relevance to the DOD acquisition and sustainment communities. In providing the opportunity for key representatives from different communities to examine the feasibility of new technical topics into existing policy, the workshop was designed to open new communication channels to address key issues, such as improved interaction between policy and S&T; balancing public laws and policies; converting S&T initiatives into policies; integrating maintenance and reliability strategy; prediction and management in the acquisition cycle; unique policy/ philosophy differences between services; and how industry and academia can help with important issues like structural health monitoring. It is anticipated that the end results will enhance the improvements in the design and performance of DOD platforms.

The overarching goals of the 2-day workshop were as follows:

- Develop strategies or tools to successfully bridge material science and corrosion engineering curricula knowledge bases for prospective students entering the workforce.
- Improve existing strategies, objectives, and processes to prevent, detect, and treat corrosion and its impacts on military platforms, specifically equipment/materiel and infrastructure.
- Reduce the negative connotation associated with corrosion, the operational effects of corrosion tracking, and the costs for controlling corrosion by implementing the best practices and best value decisions.
- Attract and train the corrosion science and engineering personnel necessary to quickly identify and understand materials corrosion issues and exploit opportunities from emerging CPC technologies.

4. Keynote Address and Panel Discussions

4.1 Keynote Address

Dr Lew Sloter, the Associate Director, Materials and Structures, Office of the Director, Defense Research and Engineering, gave the initial keynote speech titled “A Not-Too-Serious and Wholly Anecdotal History of Corrosion”.

Dr Sloter started by describing the ancient Egyptians—the builders and architects who designed structures to immortalize their kings with materials that would last the longest. Corrosion engineering awareness has existed since the first time a structure was known to degrade because of environmental effects. Members of the audience were then interactively quizzed on their knowledge of aluminum alloy compositions and briefed on the F-8, F-18C/D aircrafts, where there was extensive use of magnesium and aluminum 7050 and other aluminum series.

Dr Sloter’s primary message was corrosion management and knowledge of alloys. Corrosion management applies to everything we design and build in this nation and around the globe. Corrosion engineering is the application of fundamental science to problems or challenges that involve personal safety, structural reliability, and environmental impact. In his presentation, Dr Sloter stressed that research scientists and policy leaders should not be expected to have the expertise of corrosion engineers, but they should be aware of when and where to ask corrosion engineers for technological support.

4.2 Plenary Address

The plenary address was presented by Mr Steve Spadafora, Senior Technical Advisor, Engineering and Technology Solutions Division, at Leidos Inc., and former Department of the Navy Corrosion Control and Prevention Executive.

Mr Spadafora emphasized the direct impact of the cost of corrosion (Table 1) and corrosion RDT&E integration, as well as lessons learned on DOD acquisition, readiness, and funding. He referenced that the 2005 (DOD 2005) congressional definition of corrosion had expanded its reach to all materials and the DOD definition of corrosion as: “The deterioration of a material or its properties due to a reaction of that material with its chemical environment” (Corrosion Policy and Oversight Office 2011). He also cited DOD studies regarding the cost and impacts of corrosion on availability of various classes of materiel (Table 2).

Table 1 DOD cost of corrosion (most recent studies, $ in billions)

Study year baseline	Study segment	Annual cost of corrosion	Corrosion as a percentage of maintenance	Data
2009-2010	Army aviation and missiles	$1.5	20.9%	FY2007 and FY2008
	Marine Corps ground vehicles	$0.3	12.3%	FY2007 and FY2008
	Navy and Marine Corps aviation	$2.7	23.0%	FY2008 and FY2009
2010-2011	Air Force aircraft and missiles	$5.1	23.9%	FY2008 and FY2009
	Navy ships	$3.3	21.6%	FY2008 thru FY2010
2011-2012	Army ground vehicles	$1.7	12.3%	FY2008 thru FY2010
	Marine Corps ground vehicles	$0.3	14.3%	FY2009 thru FY2011
2012-2013	DoD facilities and infrastructure	$3.0	14.4%	FY2009 thru FY2011
	All other DoD segments	$3.6	17.9%	FY2009 thru FY2011
	Army aviation and missiles	$1.9	21.9%	FY2009 thru FY2011
2013-2014	Navy and Marine Corps aviation	$3.6	28.2%	FY2010 thru FY2012
	Air Force aircraft and missiles	$5.9	25.2%	FY2010 thru FY2013
Total DoD annual corrosion cost		**$23.3 billion**	**20.7%**	

Source: Impact of corrosion studies sponsored by OSD corrosion policy and oversight office, executed by LMI, Inc.

Table 2 DOD corrosion impact on availability

Study year	Study segment	Annual non-available time attributable to corrosion	Average non-availability per end item attributable to corrosion	Data baseline
2010–2011	Army aviation and missiles	1,717,898 hours	17.4 days	FY2008 and FY2009
	Navy and Marine Corps aviation	95,237 days	26.5 days	FY2008 and FY2009
	Air Force	2,102,476 hours	15.9 days	FY2008 and FY2009
2011–2012	Army ground vehicles	662,649 days	1.7 days	FY2008–FY2010
2012–2013	Marine Corps ground vehicles	209,115 days	3.3 days	FY2009–FY2011
	Army aviation and missiles	2,028,590 hours	19.7 days	FY2010–FY2012
2013–2014	Navy and Marine Corps aviation	116,484 days	29.9 days	FY2010–FY2012
	Air Force	2,259,412 hours	16.6 days	FY2010–FY2013

Source: Impact of corrosion studies sponsored by OSD corrosion policy and oversight office, executed by LMI, Inc.

Mr Spadafora also mentioned other safety studies that related to the loss of lives due to corrosion damage. The optimal time for inclusion of CPC planning and execution is crucial and should be a significant concept very early in the acquisition process (Fig. 1). All acquisition programs respond to validated capability requirements. The Life-Cycle Sustainment Plan (LCSP) details and addresses the sustainment metrics, risks, implementations, and recommendations. At pre-Milestone A, the LCSP should begin in the Materiel Solution Analysis (MSA) phase that describes the notional product support and maintenance concepts used to determine the sustainment requirements optimizing readiness outcomes and minimizing life-cycle cost, as shown in Fig. 1.

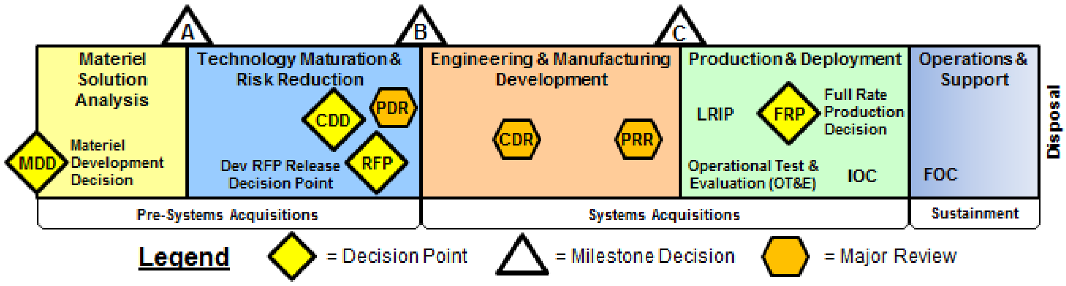

Fig. 1 Defense acquisition process (source: Defense Acquisition University)

Milestone A: LCSP evolves from a strategic outline to a management plan describing the sustainment efforts in the system design and acquisition processes to achieve the required performance and sustainment outcomes that are necessary to ensure required Warfighter capabilities.

Milestone B: LCSP evolves into a detailed execution plan for how the product support package can be designed, acquired, and sustained, and how such a sustainment will be applied, measured, managed, assessed, modified, and reported from system fielding through disposal. The LCSP is submitted with the acquisition strategy prior to Milestone B, and the executive summary is included in the acquisition strategy.

Milestone C: LCSP describes the content and implementation status of the product support package to achieve the sustainment key performance parameters and key system attributes.

Mr Spadafora recommended that the most effective place to begin CPC planning is at pre-Milestone B and at technology readiness level (TRL) 6. His key points in making this assertion are as follows:

- It is difficult to implement the CPC technologies with widely different sources of funding and varying expiration dates because contracting is often notoriously disruptive and difficult.
- The program managers (PMs) are under a great deal of pressure to have low "drive-away, sail-away, and fly-away" acquisition costs, rather than focusing on the real issue of *total* life-cycle costs. The PMs and the product support managers are responsible for the content and preparation of the LCSP; they should work with the user, the product support managers, product support integrators, and the product support providers to document performance and sustainment requirements specifying objective outcomes, resource commitments, and stakeholder responsibilities. Because PMs typically serve up to a 3-year term, their personal performance metrics typically focus on 3 short-term constraints

of cost, schedule, and performance rather than the minimization of total life-cycle costs.

- The CPC community needs to find a better way to translate their corrosion mitigation data and experiences into terms that PMs understand. The overarching idea is to show that data-driven, corrosion-reducing concepts will provide a real impact on reducing life-cycle costs. The following comments and responses from the audience have been recorded:
  - Mark Bounds of the US Army Materiel Systems Analysis Activities (AMSAA) inquired on how the Operational Mode Summary/Mission Profiles (OMS/MPs) fit across the life cycle of a particular system and how the location of the system is taken into account. An OMS/MP serves as an operationally based road map for formation/system design, test and assessment planning, estimation of cost/burden for the formation/system, and life-cycle-management insights. An accurate and thorough OMS/MP based on the combat scenario is critical to ensuring that the fielding of new equipment will meet the Soldier's needs in battle.
  - Mr Spadafora accepted that systems should be designed on the basis of the current situation, and we should use the lessons learned from comparable already fielded systems.
  - Mr Spadafora asserted that is too expensive and unrealistic to design systems for the worst-case scenario.
  - Mr Bounds (AMSAA) considered that it is important to accurately record the service location and duration for each individual piece of equipment during its field service life.
  - Mr Matt Koch of the US Marine Corps (USMC) stated that the USMC made maintenance decisions based on testing data and considers the overall mission profile as each item shifts from one region to another over time.
  - Mr Vince Hock of the US Army Engineer Research and Development Center, Construction Engineering Research Laboratory, also referenced the importance of having proper and approved storage facilities to facilitate superior equipment protection conditions.

4.3 Special Industry Perspective

The special industry perspective was given by Dr Beth Ann Pearson, who is the Global Product Manager, Metals, Military, and Plastics, at Sherwin-Williams Paints. Dr Pearson's discussion topic was titled "Corrosion Technology Transition and Product Insertion: Successes and Lessons Learned – An Industrial Perspective".

Dr Pearson discussed the advantages of working with DOD and private industry; private industry leaders offer a source of innovative direction and are willing to form a constructive partnership with the DOD. She discussed the various motivations that drive industry to be innovative. The motivations include the "first" to market; doing the "right thing"; gaining technological edge; maintaining relationships; responding to mandates, pressure, and preserving a respectable status. Dr Pearson listed the following industrial coatings and corrosion successes:

- Reduction of volatile organic compounds in coatings by the use of safe, environmentally friendly technologies.
- Thin layer coating technologies play a prominent role in promoting adhesion and enhanced corrosion products protection.
- Technology growth in the chemistry of powder coatings are influenced by changes and improvements in the production technology for powder coatings as well as developments of new application techniques.
- Advances in chemical agent–resistant coating (CARC), which is required on all combat equipment, combat support equipment, and combat service support equipment. The US CARC system is a combination of pretreatments, primers, and topcoats. After surface preparation and pretreatment, vehicle exteriors are painted with an epoxy primer, then with an aliphatic polyurethane topcoat. The interior of hull-type vehicles also gets epoxy enamel over the epoxy primer.
- Water reducible approved coatings include the water-dispersible CARC. These water-based coating technologies represent superior durability and environmental compliance. CARC has been very successful at protecting America's assets against corrosion and prolonging service life with enhanced camouflage capabilities. Every asset that the DOD owns, whether a piece of ground equipment or a rotary aircraft, has a requirement for CARC.

Some other comments and observations include the following:

- The user is hesitant when it comes to using CARC water-based coating technologies.
- Part of the problem is that users are content with the existing technologies and are therefore reluctant to change.
- The services have had success using the enhanced water primer adaptation along with the enhanced water-based primer adaptation.
- Enhanced water primer has been widely accepted by the military.

Dr Pearson suggested that industry should move toward compact systems by removing redundant steps or by combining process steps wherever appropriate to increase efficiency and effectivity.

Industry perceptions of DOD include the following:

- DOD’s strong interest in new and novel technologies
- Slow reaction
- Slow adaption
- Slow/unwilling to implement
- Strong environmentally friendly focus
- Services/branch variances with weak communication and interservice communication
- The politics of inertia mindset, where “radical” is associated with “change”

The USMC, in collaboration with industry, is a key leader for other military agencies, with their green thrust advancing the use of water. Water-reducible coatings are beneficial to performance and durability by reducing corrosion; however, industry needs DOD support to move forward. Challenges for using water-reducible coatings include the following:

- Culture (reluctance to introduce new products)
- Reputation
- Politics
- Experience

The optimism of the water-reducible coatings, environmentally friendly coatings, and industry perspective on water-reducible coatings lacks a reality check:

- Proven performance (of current version?)
- Inferior performance (concern with new item?)
- Minimal cost differential
- Complicates inventory
- Larger inventory (with additional new items?)

Waterborne technology is still favored but is seen as a future trend and important in coatings developments:

- Novel technologies
- New test capabilities
- Utilize what we have now
- How to drive innovation into use?

4.4 Panel Discussion: Corrosion S&T and Policy

Chair: E Dale Thomas; **Members:** Doug Dudis, Joe Menke, Beau Brinkeroff, Charles McNamara, Glen Sturtevant, and Fritz Friedersdorf

Challenges for the S&T and policy community include the following:

- Implement new technologies and develop cost-effective corrosion models.
- Incorporate corrosion metrics into key performance parameters or other metrics such as reduced life-cycle costs.
- Encourage corrosion experts to engage early in the procurement cycle, especially making certain that design drawings specify corrosion-resistant structural materials and treatments.
- Develop corrosion databases and corrosion models for predictive evaluation.

Testing methods for realistic prediction of performance include the following:

- Leverage technologies as much as possible from existing systems in academia and industry.
- Present significant technical data (that was normally provided to technical personnel) to the PMs.

- Gain a better understanding of the acquisition system and requirements to have a more meaningful technical impact on the procurement process.
- Improve inspection, quality assurance (QA), and quality control (QC) processes. As an example, CARC that is typically used to coat land defense vehicles and equipment requires proper QA/QC. CARC has basic processing requirements for proper application to assure that the product can achieve higher levels of performance, durability, and survivability.
- Request development of portable measurement tools for field use to 1) provide measurements/data for different operating environments exposures and 2) meet the demands of end users.

Lessons learned:

- Composite materials work well as a whole. However, composite connectors have not performed well because of problems with loss of electrical continuity and electromagnetic interference.
- Single coatings work well, but high-temperature nonskid coating problems persist as a challenge.
- Collaboration is needed with the PM to provide a satisfactory primer coating on artillery pieces. Specifically, corrosion is a prevailing problem, for instance, on the howitzer gun tubes that heat up during firings.
- Accelerated test methodologies need to incorporate test specimens and testing conditions more representative of field service environments.
- Earlier consideration of corrosion in the acquisition process requires the ability to understand possible outcomes in service life (by using models and predictive tools, as well as compiling sufficient corrosion measurement databases to feed those models).
- Industry and universities are leaders in the development of corrosion-resistant materials where "innovation is in the application".
- Understand the precise application and pass the requirements to S&T. Challenges include keeping acquisition and operational costs to a minimum.

4.4.1 Policy Briefing: Origin and Progress of OSD Corrosion Office Strategic Corrosion Plan

Mr Rich Hays, Deputy Director, DOD Corrosion Policy and Oversight Office, presented a briefing titled "Origin and Progress of OSD Corrosion Office Strategic Corrosion Plan". His discussion points are as follows:

- The CPO office is responsible for facilitating viable corrosion prevention, control, and mitigation program for both equipment/materiel and infrastructure systems in DOD.
- The overarching corrosion prevention and mitigation strategy is to transcend the traditional corrosion control methods, organizations, management, and funding approaches, and to apply modern technology and management techniques to prevent and control corrosion throughout the life cycle of systems, facilities, and materials.
- The military services and departments should develop strategic plans that are consistent with department-wide plans and objectives. This strategy would establish procedures to hold major commands and program offices (that manage equipment and infrastructure systems) accountable for achieving the strategic goals that would include corrosion prevention, control, and mitigation.
- A discussion of the laws and regulations that currently govern the CPC efforts as well as the policies and guidance that the CPO office is revising.
- CPO is implementing a dynamic and effective CPC organization at the highest level in OSD.
- CPO is attacking corrosion early in the acquisition and construction cycle during the various design, manufacture, and assembly stages.
- The date for the next DOD Technical Corrosion Collaboration (TCC) has been rescheduled to be held in Pittsburgh, Pennsylvania, on 15–19 November 2015, concurrent with the DOD and TCC.
- The TCC is not a CPO or DOD employee training program. He hopes that the TCC will train and provide the next generation of corrosion engineers to fill many job categories within the CPC workforce, including PMs, as well as within industry, such as original equipment manufacturers.
- Some of the ongoing long-term CPO efforts include improving accelerated corrosion and fatigue testing methods to better simulate in-service

exposure conditions and to improve the predictive capacity of galvanic and other corrosion degradation mechanisms.

- The main focus points for the CPO were to provide information and solutions that are important to the customers (i.e., meet their needs, not just conduct projects that are interesting to the labs); to obtain quantifiable databases for corrosion; to cultivate and encourage the next generation of corrosion-knowledgeable experts; and to improve communications between the services, as well as with industry and academia.

4.5 Panel Discussion: Universities as a Valuable Asset in Filling the Personnel Pipeline – How Industry and Universities Can Help Solve Unique DOD Problems

Chair: Dr Rudy Buchheit; **Members:** Dr Barbara Shaw, Dr Rob Kelly, and Ms Sue Louscher

The DOD has raised the stakes of its partnership with academia by trying to align the research goals of DOD corrosion prevention experts with those of university scientists. The role of universities in attracting students into the corrosion field is critical and significant. Comments from this panel and evidence of that partnership include the following:

- DOD and academic corrosion scientists began a formal partnership in 2007 when the DOD Corrosion Office formed the original University Corrosion Collaboration, a congressionally supported effort. Participating schools included The Ohio State University, The University of Virginia, The University of Akron, Southern Mississippi University, The University of Hawaii, and the US Air Force Academy. Now renamed the TCC, it also includes The Naval Postgraduate School, the US Naval Academy, and the Air Force Institute of Technology.

- The Fontana Corrosion Center at The Ohio State University is one of the premier academic research departments for corrosion and oxidation in the world. The Fontana Corrosion Center is responsible for maintaining the vitality of academic corrosion research and has distinguished corrosion professional graduates working all over the world.

- The University of Akron has taken on an unprecedented new role in reversing corrosion’s costly economic and safety consequences by offering the nation’s first baccalaureate program in corrosion engineering. The school offers BS and MS degrees with a possible interdisciplinary PhD degree for those who are interested in advanced graduate study.

- An important UCC/TCC goal is to expose students and engineers to opportunities as corrosion technologists and provide them with sufficient information and training.

- It was suggested that we change the common paradigm by making corrosion a first-choice degree instead of having an engineer develop corrosion awareness through a backdoor or accidental evolution. This can be achieved by exposing technologists and engineers to corrosion early in their professional career, potentially as early as secondary/high school. Certainly making corrosion a more exciting and interesting discipline will change that overall perception.

How can universities help increase and deepen CPC training?

- Provide short-term courses in corrosion technology to help working professionals gain that knowledge or provide refresher CPC courses. There are also longer 1-year, non-thesis master's programs in corrosion available for training.

- Degrees can be packaged differently for attracting a broader range of students, such as offering associate's or online degrees for technicians.

Methods of recruiting corrosion engineers and technologists:

- The DOD has not been successful in attracting and retaining recent graduates, especially when it offers lower salaries compared to the more competitive salaries offered by private industry, such as the oil and gas industries. Therefore, career fairs are not the most effective way to recruit corrosion specialized students. More effective methods may include having DOD personnel perform demonstrations or give presentations on corrosion to students on campus to pique their interest.

- Internships are another potential alternative; since government organizations have a slow and tedious hiring process, offering internships or post-doc appointments may help sustain the interest of prospective candidates.

Research collaboration:

- Universities tend to focus more on basic research activities. However, it is also important for universities to expand their technical coverage to include applications aspects of their applied research, such as those being offered by TCC programs.

- Encouraging increased opportunities for collaboration between DOD and industry, coatings companies, and early prototype developers by reducing intellectual property issues.
- Spread the TCC concept model further by involving more/different military departments (especially more collaboration on their applied projects).

4.6 Panel Discussion: Corrosion Metrics to Measure Risk or Assess Impact in S&T and Transition Projects; and How to Assess the Long-Term Impact of S&T Investment in Mitigating Corrosion Degradation

Chair: William Needham; **Members:** Dr Airan Perez, Dr Gaurang Bhargava, Dr Jerry Frankel, Dr Greg Shoales, and Dr Larry Fitzgerald

Cost-related metrics for assessing the impact of corrosion degradation:

- Using cost-benefit analyses that also allow for prioritizing and inclusion of different nonfinancial metrics (e.g., safety, durability, functionality).
- The DOD uses return on investment (ROI) calculation to assess technology demonstration projects. This has proven to be a good method because of its ability to track changes over time. The ROI calculation can be beneficial, especially when used early for each project, allowing a quantitative measure for the feasibility of that project. Calculating an ROI may not be the best method for measuring a project's viability (especially when the estimated/projected costs are somewhat uncertain). However, it can be useful in comparing different projects with equivalent levels of technical complexity and cost uncertainty.

Measuring risks:

- Risk can be viewed as being based on the accuracy of the test results in comparison to those in real life results.
- Risk assessment models can be useful. However, accurate inputs for each model are important to decrease quantitative risk uncertainties.
- Failure testing is also important to mitigate any risk associated with those inaccuracies. Do not limit testing methods to only those tests that just evaluate specification metrics. Failure mechanisms should also be evaluated to provide a better understanding of the performance of that particular system or its specific component of interest.

4.7 Panel Discussion: Unique Policy/Philosophy Differences between DOD Laboratories

Chair: Edward Lemieux; **Members:** Frederick Lafferman, Dr Kevin Kovaleski, Dr Margaret Roylance, and Andrew Sheetz

Opening remarks:

- The US Army particularly takes procurement and operating costs into account. Therefore, all PMs should integrate those cost considerations into the technological systems they are responsible for.
- The USMC has a good/quick turnaround implementation record due to its smaller size (relative to other services) and positive relationships with its vendors.
    - When it comes to aviation components, corrosion has top priority and cost is not as important.

Interactions among services:

- The services have acted independently in the past, creating service-specific individual specifications and standards. However, by recognizing their increasingly common interests, the services have now started to work together to create common specifications.
- The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) perform many of the DOD's environmental research programs. By harnessing the latest S&T developments, they have improved environmental performance, reduced costs, and produced enhanced and sustained mission capabilities for DOD's platform and infrastructure systems.
- These programs are responsive to environmental technology requirements that are common to all of the military services; thus, while complementing the services' research programs, SERDP and ESTCP also promote partnerships and collaboration between academia, industry, the military services, and other federal agencies. SERDP and ESTCP harness the latest science and technology developments and, as a result, produce innovative, cost-effective, and sustainable solutions to meet DOD's environmental challenges. The services should work together to develop statements of need for SERDP/ESTCP initiatives.

- Workshops are critical to these programs; current budgetary restrictions limiting workshop attendance have been damaging to all these collaborative activities.

Advance testing techniques:

- Better accelerated testing techniques are needed, including multiple options to evaluate corrosion instead of just the currently used ASTM Salt Fog Test. Prototype development and validation of such advanced testing equipment would also be useful.
- Although full vehicle durability testing of ground vehicle systems has been very helpful for ground vehicle acquisitions (having shown better-performing fleets of ground vehicles), it is impractical for ships and probably for aircraft.

Transition:

- Employ metrics that better address the customer's needs.
- Corrosion action teams with suitable training and better definitions of the accompanying requirements are needed for a successful transition.
- PMs and Program Executive Offices (PEOs) must be made more aware of important corrosion issues during the project proposal evaluation phase.
- Technology transfer between government laboratories and universities would be significantly improved with better inter-organizational communications.
- Compartmentalization/stove-piping makes all transitions more difficult.
- Uniformed service personnel are sometimes skeptical about the value of S&T; this is especially true about their awareness of corrosion, because it is a slow, long-term, performance-degrading problem.
- A satisfactory cost/benefit analysis is needed to convince a PM to include anticorrosion metrics.

4.7.1 Keynote Briefing: Prevention and Control of Corrosion Is a Life-Cycle Activity – Design the System, Design the Product Support System, Support the Designs

Dr Roger Hamerlinck, Senior Acquisition Policy Specialist, Office of the Assistant to the Secretary of the Army (Acquisition, Logistics and Technology), presented a briefing titled "Prevention and Control of Corrosion Is a Life-Cycle

Activity – Design the System, Design the Product Support System, Support the Designs” with the following comments:

- Mr Steven Carr has been recently selected as the Army’s new Acting Corrosion Control Program Executive.
- A directive memorandum for the Army CPC program is being approved, and the Army Reserves have already published their own policy for its implementation.
- He stated that S&T and CPC programs are central to Joint Capabilities Integration and Development System activities involved in its Planning, Programming, Budgeting, and Execution (PPBE) processes as well as any acquisition process are S&T and CPC. These respective requirements and knowledge bases help guide where things fit in and also are affected by specific S&T and CPC, technologies can be successfully applied.
- In addition to S&T or CPC personnel, everybody involved is important and plays a role in any PPBE process.
- Tier 1 Requirements are those that are the most critical to the purpose and intent of the PPBE process as well as the standards of which they are a part. Tier 2 Requirements represent an additional level of inquiry that must be undertaken when a registered entity does not display clear compliance with those most critical of Tier 1 Requirements. Tier 1 and 2 Requirements get higher priorities while those from lower tiers often are generally cut. If sufficient CPC considerations impact another higher priority requirement, such as survivability, promotion of CPC requirements to the Tier 1 level can be considered.
- Corrosion SMEs, especially from the CPC and S&T communities, need to be more involved in existing integrated product teams. A better outcome would occur if their expertise were used to influence those decision processes.

4.7.2 NACE Briefing: The Role of NACE Technical Organizations in Guiding Corrosion Policy

Dr Harvey Hack, President of NACE International and Senior Advisory Engineer at Northrop Grumman Corporation, presented a briefing titled “The Role of NACE Technical Organizations in Guiding Corrosion Policy” with the following comments:

- NACE International was established in 1943 by 11 corrosion engineers from the pipeline industry known as the National Association of Corrosion Engineers (NACE).
- NACE International is the corrosion authority, serving approximately 33,000 members in 116 countries; it is recognized globally as the premier authority for corrosion control solutions. The organization offers technical training and certification programs; organizes conferences; prepares and distributes industry standards, reports, and publications; publishes technical journals; and facilitates academic, industry, and government relationships.
- The corrosion policy objectives that drive the activities of NACE International and other corrosion associations include actions to improve public safety, such as minimizing dangers and issues associated with bridge and pipeline failures; reduce life-cycle costs for infrastructures by lowering costs for maintaining and replacing bridges, water lines, and other infrastructures (thus reducing costs to taxpayers); protect the environment from oil spills and other disasters; reduce the depletion rate of natural resources by emphasizing preventative maintenances and repairs rather than replacements; and prevent catastrophic failures, such as plant explosions, that cause lives to be lost and the associated additional costs to repair damaged assets.
- NACE works toward making relevant governmental policy changes by working with legislatures throughout the United States using its political action committee. Other means include educating and communicating those facts on issues to policy makers; providing information to policy makers in meeting their corrosion policy goals; educating and certifying corrosion professionals; and "selling" good corrosion policies to the general public.
- The NACE International Institute has been awarded a contract for providing data management services for the upcoming International Measures of Prevention, Application, and Economics of Corrosion Technologies (IMPACT) study.
    - Previous studies on the costs of corrosion have focused only on costs in the United States for a few industrial sectors. The IMPACT study will encompass a much broader range of information by including global data and will take a corrosion management practice approach. In addition to analyzing the cost of corrosion, this study will compare

various countries' practices in an effort to identify the best corrosion management practices globally.

- Global in scope, the study will focus primarily on the information collected from Australia, Canada, Europe, India, Japan, Latin America, the Middle East, the United Kingdom, and the United States. There are also several industrial advocates worldwide who have committed to providing support and data to the study or have committed to serving as technology contributors.
- The resulting publication will inform policy makers and evaluate the costs of corrosion and control worldwide. The anticipated publication date is March 2016.

4.8 Discussion Panel: Tools for Acquisition Decision Making: The Role of Accelerated Corrosion Test and Computational Tools; Structural Health Monitoring/Facilities/Sustainability (Life Extension)

Chair: Dr Virginia DeGiorgi; **Members:** Mark Bounds, Dr Kevin Kovaleski, Brian Placzankis, and Chad Hunter

Opening remarks:

- There is a tendency for 6.1 basic researches and 6.2 applied research efforts to strive for perfection; this goal is not always practical.
- There are limitations to using the data from the ASTM B117 (1997) as the salt spray testing procedure whenever ranking the relative corrosion performance of treatments and materials. Several studies have come to the conclusion that ASTM B117 does not provide a good test for the relative performance of specific coatings on aluminum alloys or that it fails to correctly predict/rank the protective effect of aluminum-zinc alloy protective coatings (with different alloy compositions) on cold-rolled steel substrates or rank many other coatings (Colvin et al. 1997). Clearly a better test than ASTM B117 salt fog is needed.
- Better galvanic corrosion models and sensors for use on aircraft are needed.
- Collaborative programs with environmental groups, such as the Army with the CPC and another with the Toxic Metal Reduction program, are encouraged.

- Developments of sensor systems that collect data and communicate with computers/users are needed. These sensor systems should be capable of diagnosing problems (e.g., by using a proper corrosion sensor instead of a humidity sensor).

Key points and key issues:

- Because the DOD has taken aggressive steps to curtail conference attendance, it has installed strict policies and controls to ensure that all conference attendance is cost effective. Unfortunately, the mission and programmatic goals of each agency were especially hindered or disadvantaged by these conference-related travel restrictions. There are circumstances in which physical colocation of participants from different organizations may be necessary to successfully complete the mission; that colocation attribute is directly countered by the existing DOD directive to limit travel.

- The entire DOD community (studies, budgets, programs, acquisition overlaps, etc.) should share the responsibility of preventing corrosion problems for current or future systems.

- The institution of sound CPC practices at the early stages of system development can result in a reduction of total ownership cost. In addition, conducting effective and timely CPC planning and execution is not as elusive and difficult as commonly assumed.

- Policy generally tends to be formulated to address problems; policies are mandatory, whereas guidelines are optional.

- By engaging in Reliance 21 and OSD S&T strategy activities (studies, budgets, programs, acquisition, and eliminating overlaps, etc.), scientists and engineers can share information, align technical efforts, coordinate priorities, and create a mutual support network.

- Corrosion is a subset of the Reliance M&MP COI; however, since corrosion has a cross-cutting impact, it should be a subset of every technical area COI because it affects the capabilities of all weapon systems.

- Not all aspects of the COIs for Reliance 21 must include CPC activities; however, its overarching requirement is still there.

- Is S&T staff sufficiently involved with acquisition strategies? It seems rare to see S&T staff working on integrated product teams. Since the quality of a product is determined by the role of those involved, reviews by corrosion-aware S&T staff should be encouraged.

- If reviewing CPC on integrated product teams is not a high-level requirement during acquisition, corrosion awareness input from our S&Ts will not be appropriately integrated into acquisition programs.

Technology gaps:

- Availability of precise, definitive sensors
- Availability of better and more accessible databases containing corrosion-related repairs and maintenance activities
- Tailorable test protocols that can be modified to simulate any given service environment
- More inclusive corrosion risk models that adapt to service location–based environmental variables

4.8.1 Briefing: The Challenges to Changing the Perception of Material Degradation

Dr Dave Robertson, Air Force Corrosion Control and Prevention Executive, gave a briefing titled "The Challenges to Changing the Perception of Material Degradation".

Dr Robertson was concerned and addressed the general public's indifference to corrosion. According to Robertson, "Corrosion adversely affects personal, corporate, and national assets". Corrosion is a narrow and negative term that most people think of as merely rust on a metal. We must have an urgent obligation to change that misperception.

What can the S&T community do?

- Reverse the ongoing outsiders' conception that "it is not an S&T issue".
- Change the present perception that corrosion is merely a near-term, minor problem-solving activity.
- Emphasize that the most realistic approach to producing more corrosion-resistant systems will involve using revolutionary new materials and processes that will be the result of long-term scientific endeavors.

Insufficient corrosion impact policies are a real problem. How does one make corrosion policy issues more prominent?

- Change incorrectly focused policy; a weak policy often causes more damage than good.
- In contrast, by implementing more effective policies, one can achieve lasting beneficial results on the performance and readiness of such systems.

Actions to change the current negative perception about corrosion:

- Communicate the seriousness of corrosion degradation on the effectiveness of military and industrial operations by using plausible metrics.
- Communicate the concept that by proactively reducing corrosion degradation with specific actions, one can dramatically reduce or eliminate many problems.
- Establish a vision of "What is Possible" when appropriate S&T actions are used. This vision must relate how new, recent, and developing technological discoveries have the potential to become long-term game changers.
    - This vision should relate directly to how new and developing technologies could capture the imagination of youngsters and early-career professionals as well as senior leaders.
    - There is a need to build a corrosion-aware community with a broad range of people from entry- to senior-level technologists as well as involved political leaders, all of whom have a real stake in that vision. That group must have a critical mass or minimum size that would be able to achieve and maintain success (i.e., be self-sustaining).

Dr Robertson proposed changing the commonly accepted description of "corrosion" beyond its currently narrow "metal rusting" definition to a broader definition within the S&T community. An important action for the S&T community is to convince the S&T policymakers to establish new definitions to change that perception. "Corrosion" is a term too common to the general public, so it is hard to change. The importance of changing the perception of material degradation was emphasized. It is important to adopt this broader and more positive definition that would cover not only traditional corrosion, but also other issues of environmental degradation processes, such as (but not limited to) polymeric (UV) degradation, tin whisker growth in microelectronics, hydrogen embrittlement, fretting corrosion, organic material decomposition, and the atomic effects of corrosion.

Dr Robertson also noted that each person in the community is important in regard to changing the general perception on material degradation. However, there was strong pushback from the audience to the effect that changing the name of corrosion to something that sounds administrative would be disruptive and probably counterproductive. Corrosion is too complex because it is a phenomenon defined broadly as a material condition.

4.8.2 Briefing: Alternative Futures for Corrosion and Degradation Research

Dr Robert Hummel, Chief Scientist at the Potomac Institute for Policy Studies, presented a briefing titled "Alternative Futures for Corrosion and Degradation Research".

He recently studied corrosion degradation mechanisms and outcomes, and his work was published as a book entitled "Alternative Futures for Corrosion and Degradation Research", printed by the Potomac Institute (2015). The study was sponsored by CPO and chartered with a directive to find "out of the box" research directions. The primary focus of this published study was to address how science can be applied to meeting the needs of the 21st century.

Corrosion and degradation of systems have enormous impacts:

- Costs of corrosion are enormous.
- Impacts beyond costs include health and safety, reliability, availability, and future replacements.

The impacts of corrosion and the need for corrosion control are national in scope:

- Sectors include defense systems, infrastructure, energy, vehicles, manufacturing, and products.
- Responsibility for it cuts across all federal agencies/departments as well as all segments of private industry.

The fundamentals of corrosion and degradation vary widely and are complex, where a single root cause for failure may not be identifiable, and a "silver bullet" solution may not exist.

Much of the ongoing research and development (R&D) activities in corrosion control are incremental and are motivated by short-term ROIs; insufficiently leveraged by the inclusion of new computing and information technologies and advanced manufacturing processes; more empirical than analytic; and lack collaboration between personnel within and outside of the corrosion field.

The functional approaches to implementing corrosion control occur in the design and production phases; the development of improved performance materials and coatings; and during the inspection and maintenance phases of systems.

There are opportunities for revolutionary advances by applying new directions in corrosion research:

- By implementing corrosion-aware designs.
- By using computational methods to discover, or to identify, recently formulated novel structured materials and coatings; or replace conventional materials and coatings with higher-performing alternatives.
- By improving the effectiveness of maintenance operations by using massive sensing and big data analytics.

Responding to the question "If we have to build fewer systems with increased capabilities, why not apply better pre-Milestone A disciplines?" he agreed and recommended that corrosion control be included as one of those critical pre-Milestone A requirements.

Dr Hummel provided the following recommendations:

- The government should ensure that a robust national R&D program for corrosion and degradation control is planned and funded. It could be branded as "material sustainment" research.
- The government should increase the amount of active collaborations by sponsoring cross-agency and multi-industry national R&D efforts and programs. The objective of these national programs should be to direct R&D toward solving important national needs.
- The funding level of R&D programs in corrosion control should be sufficiently large to allow the pursuit of multiple alternate approaches.
- The government should endeavor to rebalance the research enterprise in corrosion control to include more long-range objectives. This shift would accomplish the following:
    - Achieve more balance between short-term applied and long-range research activities.
    - Increase the leveraging of new computing and information technologies, including new manufacturing processes.
    - Ensure the inclusion of more empirically validated analytic modeling tasks within programs.

    - Increase collaborations between technologists both within and outside the corrosion fields.

- Long-range research programs should be organized around functional approaches to solving corrosion control issues, such as programs in design and production that encourage developing corrosion-resistant materials and coatings, as well as better inspection tools and maintenance procedures.

- Develop and fund programs in corrosion research having new directions or approaches that could lead to revolutionary or breakthrough advances in

    - Design: where corrosion-aware tools are included;

    - Materials and coatings: where computational methods could be used to identify/formulate novel higher-performing materials and coatings, or where system components made from structured materials with new classes of unique properties can lead to higher performance systems; and

    - Improved sensitivity inspection and maintenance tools: with massive sensing, big data analysis capacities.

Over 80% of the funding spent on preventing corrosion is related to coating programs that use or develop emerging technologies to develop new paints, materials, and coatings; infrared plasma arc spraying; nanomaterials; and self-healing coatings.

Dr Hummel identified 1) new emerging coating concepts that involve graphene or other monolayer constituents; super hydrophobic or super oleophobic property coatings; and surface structures with unique electrostatic properties and 2) research that is needed to understand environmental degradation chemistry as it relates to durability, performance, and predictability.

4.9 Panel Discussion: Merging Acquisition Plans and S&T Roadmaps to Better Support ACAT Programs before Milestone B – Integrating Cutting Edge Technologies into Policy Decisions

Chair: Dr Lewis Sloter; **Members:** Dr Roger Hamerlinck, Mr Rich Hays, Mr Matthew Koch, and Dr Dave Robertson

Opening remarks:

- A major issue exists when incorporating CPC into acquisition programs that rely on commercial off-the-shelf components after passing Milestone B.
- The CPC staff should be engaging the acquisition process as early as possible; this may even involve procurement of legacy systems.
- Some programs do not exist before Milestone B, and as a result, insertion of CPC into those program plans or acquisition plans are needed.
- It is critical to take system affordability into account throughout the acquisition cycle.

Revising DOD Instruction (DODI) 5000.02 (2008) will have the following impacts:

- DODI 5000.67, "Prevention and Mitigation of Corrosion on DoD Military Equipment and Infrastructure" (2003), will need to be revised, since there is no explicit requirement for CPC planning in the revised DODI 5000.02.
- The revision of DODI 5000.67 will be an opportunity to provide more effective accountability. (In the USMC, the CPCP cost about $100,000–$150,000 to develop but may not be used after it is approved.)
- The enforcement of a CPCP is not critical if the PMs proactively take the CPC concept seriously and understand its criticality.
- These requirements are allowed to be tailored, pending the Milestone Decision Authority's (MDA's) approval.
- Intellectual property rights are important; however, they are not automatically granted until the vendor requests them.

The barriers for inclusion of a viable CPC component in contracts include the following:

- Unless CPC metrics and service life requirements are explicitly included in the contracts, they cannot be enforced.
- Unless a transition plan including corrosion measures is established early enough in the program with the PM and PEO concurrence, it cannot be enforced.
- Performance-based requirements are not useful in all situations, such as for CARC, which requires where the inclusion of all 4 parts of the coating system must first be mandated.

4.9.1 Briefing: Interfaces of Acquisition and Corrosion S&T in DOD

Matthew Koch, Corrosion Prevention and Control Executive for the Department of the Navy, gave a briefing titled “Interfaces of Acquisition and Corrosion S&T in DOD”. He echoed and cited DOD studies regarding the cost and impacts of corrosion on availability of various classes of materiel as shown in Fig. 2.

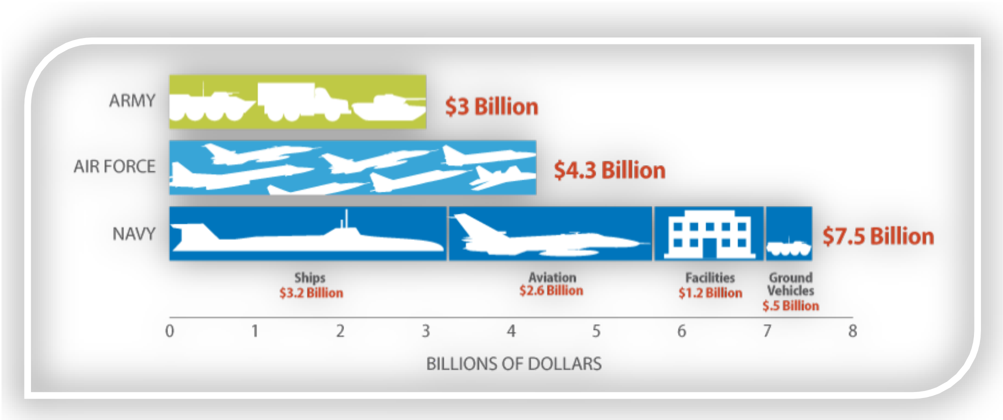

Fig. 2 Impact and cost of corrosion

Mr Koch asserted that all military corrosion S&T should support the Warfighter and the DOD regardless of any assigned TRLs. The numeric values of a TRL are a metric for estimating the technological maturity of any critical technology element for that program during the acquisition process. These are determined during a Technology Readiness Assessment study that examines program concepts, technology requirements, and demonstrated technology capabilities. TRL values range from 1 to 9, with TRL 9 being the most mature technology. The use of TRLs enables consistent and informed discussions of technical maturity when comparing different types of technologies.

The primary purpose of military research should be to increase the capabilities of weapons systems and other platforms. While some basic research is intended to increase generic capabilities and scientific understanding, the majority of funding supporting corrosion S&T should be in direct support of current or future weapon systems and other platforms. To understand its interface with the S&T acquisition process, S&T personnel must become more familiar with the acquisition process. Figure 3 illustrates how the cquisition process proceeds through a series of milestone reviews and other decision points that progressively authorize entry into the next program phase.

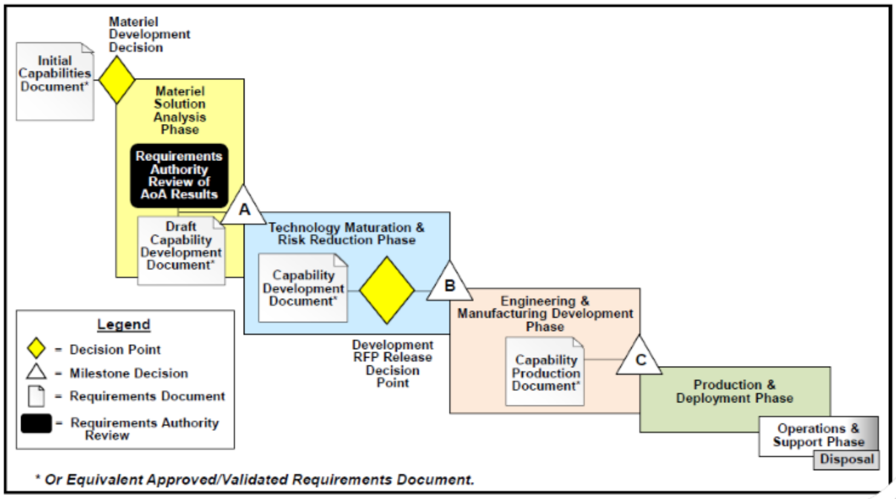

Fig. 3 Acquisition process based on DODI 5000.02 (2008)

Mr Koch's discussion focused on the sustainment requirements for CPC in systems engineering and life-cycle considerations over the entire planned life cycle of that system or platform as required by DODI 5000.67 (2003) (Fig. 3). Product support planning, especially maintenance planning and sustainment engineering, will incorporate appropriate actions to mitigate CPC risks inherent in the design of each system/platform to meet sustainment requirements.

Corrosion planning is required within the Systems Engineering Plan and the LCSP for all Program Acquisition Category (ACAT) programs. The Defense Acquisition System divides acquisition programs into 4 ACATS: ACAT I, ACAT IA, ACAT II, and ACAT III. The difference between each category is dependent on the location of a program in the acquisition process; the funding amount for RDT&E; the total procurement cost; special interest; and decision authority. ACAT I programs are Major Defense Acquisition Programs (MDAPs). An MDAP is a program that is not a highly sensitive classified program and that is designated by the USD(AT&L) as an MDAP; or that is estimated to require eventual expenditure for RDT&E, including all planned increments of more than $480 million (FY constant dollars) or procurement, including all planned increments of more than $2.79 billion (FY constant dollars).

ACAT IA programs are Major Automated Information Systems (MAIS). A MAIS is a DOD acquisition program for an Automated Information System (AIS) that is either designated by the MDA as a MAIS or estimated to exceed $40 million (FY constant dollars) for all increments, regardless of appropriation or fund source, directly related to the AIS definition, design, development, and deployment, and incurred in any single FY; or $165 million (FY constant dollars) for all expenditures, for all increments, regardless of appropriation or fund source, directly related to the AIS definition, design, development, and deployment, and incurred from the beginning of the MSA phase through deployment at all sites; or $520 million (FY constant dollars) for all expenditures, for all increments, regardless of appropriation or fund source, directly related to the AIS definition, design, development, deployment, operations and maintenance, and incurred from the beginning of the MSA phase through sustainment for the estimated useful life of the system. All defense acquisition programs are designated with a numeric ACAT value (i.e., from ACAT I through III). Acquisition, requirements, and budgeting actions are closely related and must operate simultaneously with the full cooperation and in close coordination of all participants.

ACAT II programs are defined as those acquisition programs that do not meet the criteria for an ACAT I program but do meet the criteria for a major system. A major system is defined as a program estimated by the DOD component head to require eventual expenditure for RDT&E of more than $185 million in FY constant dollars, or for procurement of more than $835 million in FY 2014 constant dollars or those designated by the DOD component head to be ACAT II. The MDA is the DOD Component Acquisition Executive (CAE).

ACAT III programs are defined as those acquisition programs that do not meet the criteria for ACAT II. The MDA is designated by the CAE. This category includes less than major AISs.

Corrosion planning involves multiple participants with program management, systems engineering, life-cycle logistics, test and evaluation, contracting, cost estimating, or budgetary expertise. This planning activity involves the following considerations:

- Technological considerations covering corrosion variables, potential solutions, corrosion impacts, and testing for corrosion (may utilize service laboratories)
- Design considerations covering material and coatings selection, design geometries, operational environment variables, and processing/finishing specifications

The corrosion topics/activities considered during each pre-milestone phase are outlined below:

Pre-Milestone A:

- Inserting corrosion language: typically related to projected operational environment and service life conditions.
- Reviewing past performance.

- Surveying similar mission platforms.
- Surveying similar platforms to eliminate existing corrosion-promoting design flaws and to estimate major maintenance costs.
- Discussing with maintainers of similar systems to identify potential corrosion problems.

Pre-Milestone B:

- Corrosion planning for that system (must identify those who make corrosion risk assessments).
- Corrosion testing of candidate system components as well as prototype materials/components/system.
- Setting up requirements to assure that each contractor identifies materials and production methods that will be used (verifiable).
- Compiling the Contract Data Requirements List: this is a list of authorized data requirements for a specific procurement that will become a part of the final contract.
- Defining the metrics to be used to monitor corrosion performance as well as the documentation of possible corrective issues and actions.

Pre-Milestone C:

- Defining which QA processes will be used to monitor high-quality manufacturing practices (e.g., material use, coating application).
- Defining protocol to approve and manage corrosion-related engineering changes.

The following operations and sustainment activities are anticipated:

- Updating the LCSP.
- Documenting corrosion maintenance procedures.
- Maintaining fleet with best-practices approach.

Proper corrosion S&T planning throughout the acquisition process, as well as for the life cycle of that asset, will result in long-term cost avoidances.

The following best practices will aid in corrosion prevention:

- Conducting design reviews that look for potential corrosion damage “hot spots”.

- Conducting tests validating the corrosion resistance of specified materials prior to those assets being fielded.
- Conducting lessons learned interviews with maintainers of similar systems during design for lessons learned.
- Developing a plan for addressing corrosion during that system's sustainment phase.
- Examining relevant corrosion research information to anticipate corrosion failure problems.
- Using corrosion S&T knowledge bases to resolve any potential corrosion failure issues, as well as identifying any capability gaps.

5. Trends and Observations

A number of important trends concerning education and corrosion, and observations related to decreasing corrosion-based failures of DOD systems and platforms that impact sustainment were discussed at the Persh Workshop:

- Continued communication is necessary across the board by facilitating DOD interactions with industry as well as those between the S&T and the acquisition communities.
- Risk aversion is inherent in the acquisition process; innovation in corrosion mitigation during new system design is subject to this sentiment. Typically, the introduction of innovative solutions and technology runs counter to the risk of aversion culture present when new weapon systems are proposed. Thus, proponents for introducing novel or appropriate corrosion resistance requirements into the acquisition process should emphasize that in addition to producing more reliable systems, these modifications can reduce the total life-cycle costs of that newly designed system.
- The inclusion of corrosion relates to changes that can affect the early stages of the procurement process and could reduce life-cycle costs in new designs.
- Given the extensive scope of introducing corrosion awareness and improvements, more inter-DOD agency interaction is needed between similar existing technical programs. DOD partnerships should also be leveraged with industrial and academic collaborators. Corrosion education and workforce development can be enhanced by providing short courses

for educating the existing workforce; meanwhile, in order to fill the pipeline with corrosion-aware students, interesting corrosion-related information should be included in the K–12 education curriculum.

Metrics for rating corrosion proposals should not exclusively favor those with ROIs but should also include other modifying criteria, such as business case analyses as well as increased readiness and availability levels.

- Enhancing tools for corrosion S&T includes those predictive models that enable data-driven decisions, appropriate use of onboard corrosion sensors, utilization of digital data to enable better product life-cycle management, improved assessments/condition-based maintenance, and the use of modified/improved accelerated testing protocols that reflect better simulated real-world conditions and in-service environments. From the initial system/product definition phase to its fielding requires to the shortest possible timeframe. The opportunity is to better couple basic research endeavors (such as those conducted by the TCC community) with application organizations or entities, such as DOD and industrial laboratories. Ultimately, the acquisition workforce would have such TCC programs included for more realistic requirements and applications for their R&D transition goals.

- The ability to input realistic life-cycle conditions—specifically, the variability in environmental conditions into viable analytic corrosion model—is needed to accurately simulate corrosion effects; similarly, such input would lead to the development of improved accelerated testing methods as well as the design of more representative configurations for those accelerated test samples. There is a need to characterize new and emerging materials, alternate substitute materials, and next-generation materials for new usage categories.

- There are already more accurate and realistic estimates on corrosion as evidenced by the use of fewer corrosion coupons as the singular corrosion test and rates.

- Transitioning corrosion-resistant technology into established programs-of-record is a longstanding challenge for the DOD. Finding novel ways to include such innovations into the process could yield great benefits. Creating acquisition PM and operator technical “pull” actions rather than accepting technical “push” actions from the S&T community has generally been the most effective means to quickly transition new technologies that meet DOD demands for the future systems.

- The optimum opportunities for introducing new/alternate technologies, materials, or processes occur as early as possible in the acquisition cycle.
- Engineer new materials by matching their properties to those material performance requirements listed by the acquisition enterprise and academia, and as well as by matching the needs of weapons systems designers.
- Clearly defined requirements and matching acceptance criteria are 2 of the most important elements of successful project development.
- Increased awareness concerning the technical and economic problems caused by corrosion has notably accelerated research into the details of the electrochemical nature of the corrosion phenomenon and the fundamental importance of the state of metallic surfaces on the performance of protective coatings.
- There is a lack of awareness on the methods, tools, and materials that can be used to enhance life-cycle corrosion performance at decision-making positions. The problem can be addressed through education on the reasons for corrosion and the methods for its control.

6. Significant Issues and Questions

The effectiveness of corrosion protection and management has been improving over the last several decades. Nevertheless, there are still many new challenges to confront concerning corrosion prediction, prevention, and control. A number of significant issues, questions, and solutions were raised during the workshop:

- What can OSD and the US Government (we) do to promote the demonstration and use of new materials with beneficial, innovative properties?
- How do we validate/certify new methods?
- What means can be used to incentivize acquisition professionals to consider and include total ownership cost as a serious decision metric?
- How do we advocate that total ownership cost reduction should be used to justify an exception to any acquisition cost cap?
- How do we reduce the cost of new corrosion-resistant materials and/or appropriately justify the higher price?
- How do we design more durable coating systems?

- Development of new or improved testing tools is needed to better correlate performance with actual field experience so that we are better at the synchronization of development activities.
- DOD acquisition programs are inherently complex and conservative; as such, they are not well suited to adapt to the inclusion of additional corrosion enhancements (better correlate with exposures), especially those that are after the acquisition program has started.

7. Recommendations

The DOD has different options to choose from in the prevention of corrosion in ground vehicles, aircraft, and naval vessels, as well as for equipment, facilities, and infrastructures. Many off-the-shelf technologies have been tested and recommended for corrosion control of current and planned weapons systems and platforms. The DOD spends about $23 billion every year for corrosion-related maintenance.

Implementing corrosion improvement technologies by the acquisition cost-conscious, performance-focused operator community will require that affordability be made a key performance parameter that can be used to validate the projected life-cycle cost reductions associated with the use of new CPC measures.

CPC is necessary to sustain battle-ready forces in the field to meet strategic national defense priorities. Many factors should be considered when evaluating and including corrosion prevention requirements in the acquisition of new weapon systems. It is vitally important to include corrosion engineering knowledge and technology from the very beginning of the design process to reduce corrosion issues over that system's life cycle. In addition to military readiness and war-fighting capability, it is necessary to develop an effective corrosion control and prevention strategy for efficiently and economically fielding sustainable weapon platforms. To instill corrosion resistance as an acquisition ethic, it is necessary to enhance communications beyond the corrosion community through continued education and outreach, and include efforts with substantial inputs from the S&T community.

The participants of this Persh Workshop concurred that there was an overarching need for inserting corrosion policies and corrosion control planning into the early stages of weapon system designs. Coordinating acquisition plans with S&T roadmap timeframes will ensure better and more coordinated support of acquisition programs before Milestone B. This will be critical to ensuring the integration of CPC planning and execution into all elements of the acquisition processes to include relevant actions by PMs, systems engineers, life-cycle logisticians, as well as T&E, contracting, and budgeting personnel.

The primary objective of this workshop was to recommend actions to government and industry that would encourage the US technical community to continue educating scientists and engineers on the effects of corrosion. The recommendations below should be followed to complement and strengthen the implementation of CPC policies and strategies:

- Insert corrosion control planning in the early stages during the weapon system designs before Milestone B to better support the acquisition programs.
- Enhance policy guidance for mandatory inclusion of prevention and mitigation of corrosion considerations.
- Develop closer industry/DOD partnerships because industry is a leading developer of corrosion-resistant materials.
- Government S&T investments need to focus on DOD applications that are unique to DOD weapons system requirements.
- Effective reliability requires resourcing standardized methodologies for performing enhanced S&T analyses.
- Establish oversight mechanisms to coordinate corrosion prevention and mitigation projects for both inter-service and intra-service collaborations.
- Engage the whole community in providing independent analyses and assessments of alternate corrosion abatement choices.
- Implement announcements, outreach, and other supportive efforts between members of the corrosion S&T and acquisition communities.

8. Conclusions

This workshop resulted in several observations pertinent to increasing the sustainment of the current and future DOD assets through the implementation of CPC. A number of significant questions and challenges were defined that subsequently led to the generation of recommendations for further actions by the technical community. DOD weapons systems will remain vital components of our defense structure far beyond their design life and are becoming increasingly degraded by corrosion and susceptible to its effects. Combatting and managing corrosion are paramount for keeping these aging systems safe, reliable, and affordable.

This workshop demonstrated the benefits of conducting periodic meetings with key personnel to assess the value of science and engineering in promoting sustainment. The strength of Reliance 21 has demonstrated that the formation of cross-cutting collaborative teams can provide strategic and technical leadership to the S&T workforce. The goal is to ensure that the DOD S&T community provides technological solutions and advice to DOD's senior-level decision makers, Warfighters, Congress, and other stakeholders in the most effective and efficient manner. This is achieved through forming an organizational infrastructure that enables information sharing, alignment of efforts, and coordination of priorities to support scientists and engineers across the DOD.

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List of Symbols, Abbreviations, and Acronyms

ACAT	Acquisition Category
AFRL	US Air Force Research Laboratory
AIS	Automated Information System
AMSAA	US Army Materiel Systems Analysis Activity
CAE	Component Acquisition Executive
CARC	chemical agent–resistant coating
COI	Community of Interest
CPC	corrosion prevention and control
CPCP	Corrosion Prevention and Control Program
CPO	Corrosion Policy and Oversight
DODI	DOD Instruction
DOD	Department of Defense
DSB	Defense Science Board
ESTCP	Environmental Security Technology Certification Program
FY	fiscal year
IMPACT	International Measures of Prevention, Application, and Economics of Corrosion Technologies
LCSP	Life-Cycle Sustainment Plan
M&MP	Materials and Manufacturing Processes
MAIS	Major Automated Information Systems
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MSA	Materiel Solution Analysis
NACE	National Association of Corrosion Engineers
NRL	Naval Research Laboratory
OMS/MP	Operational Mode Summary/Mission Profile

OSD	Office of the Secretary of Defense
PEO	Program Executive Office
PM	program manager
PPBE	Planning, Programming, Budgeting, and Execution
QA	quality assurance
QC	quality control
R&D	research and development
RDT&E	research, development, test, and evaluation
ROI	return on investment
S&T	science and technology
SERDP	Strategic Environmental Research and Development Program
SME	subject matter expert
TCC	Technical Corrosion Collaboration
TRL	technology readiness level
USD(AT&L)	Undersecretary of Defense for Acquisition, Technology and Logistics
USMC	US Marine Corps
UTC	Universal Technology Corporation

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